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NOL DROP TEST (U)

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21 JUNE 1962

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UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 62-150

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NOL DROP TEST (U)

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ABSTRACT: A modification of the Naval Weapons Laboratory, Dahlgren, Va. 1219 cm. (40 ft.) drop test and the Naval Ordnance Test Station, China Lake 305 cm. (10 ft.) drop test is set up and has been evaluated at the Naval Ordnance Laboratory, White Oak. The purpose is to find a way of accepting new explosives for fleet use without the necessity of making very difficult and expensive loadings for larger scale tests. A 45.4 Kg. (100 lbs.) weight, upon being dropped, drives a 19 mm. (3/4 in.) diameter stud into a cased explosive charge. All the energy of the falling weight is transmitted to the charge by the stud. The minimum height of drop which causes explosive action is an indication of the sensitivity of the charge.

Results to date have ordered explosives in the same sequence as the Bruceton type impact machine.

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White Oak, Silver Spring, Maryland

NOLTR 62-150 21 June 1962

The decision for or against general use of a new high explosive depends, in part, on its susceptibility to accidental initiation when exposed to the hazards of warhead loading, transportation and handling. Since safety is always relative, many laboratory tests are used to compare the sensitivity of one explosive to another, under similar stimuli. When laboratory evaluation is favorable, the next step is to find out if larger quantities respond in the same manner.

The rough handling test described in the report simulates a large scale drop test currently used by the Navy. This new test was devised as a quick, inexpensive method of evaluating explosives in larger quantity than can be handled in the laboratory. Sufficient data are not yet available to establish firm correlations with other tests but first results are encouraging. The conditions of the test are such that future mathematical analysis may yield useful contributions to our understanding of the initiation process.

The work was supported by WepTask RUME-3E-000/212-1/F008-10-004, problem assignment No. 012, Study of Explosive Properties.

W. D. COLEMAN
Captain, USN
Commander

Albert Lightbody
ALBERT LIGHTBODY
By direction

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NOL DROP TEST (U)

INTRODUCTION

Acceptance of an explosive for military use is often dependent on the ability of that explosive to pass a safe handling drop test. One recognized test is the Naval Weapons Laboratory (NWL), Dahlgren, 1219 cm. (40 ft.) drop test. This test requires that 10 Mk 54 Mod 1 depth bomb cases be loaded (unfuzed) with the explosive (about 114 Kg. per bomb) and dropped as follows: Five are raised to a height of 1219 cm. (40 ft.) and dropped onto a flat steel plate supported by a concrete pad. Survivals of this test are dropped from a height of 305 cm. (10 ft.) onto a steel plate having 19 mm. (3/4 in.) studs protruding 25 mm. (1 in.) from its surface in rows 11.4 cm. (4 1/2 in.) apart both ways.

Then the other 5 are dropped from the same heights, but in reverse order. Any deflagration causing fragmentation of the case, or results of a more violent nature, constitute a failure of the explosive to pass the test. This test originated during World War II to insure safety of handling aircraft bombs aboard ship. Since the distance between decks of a carrier was approximately 1219 cm., and the maximum height of available testing facilities was also 1219 cm. (40 ft.), this drop height became a standard test.

With the advent of guided missiles the same test was adopted for warheads by convention. As time went on, various modifications, such as the 305 cm. drop on studs, came into being, following studies made on the handling of explosive items by various means. Ordnance is exposed to potential drops from the fork lift, cherry picker, mobile crane, ships gear, shore based gear, or floating crane, with height distances varying up to 30.5 meters (100 ft.). Although the 1219 cm. drop test is still considered somewhat standard, new facilities at Dahlgren are capable of dropping full scale items from heights in excess of 30.5 meters.

The Bureau of Naval Weapons suggested to the Naval Ordnance Test Station (NOTS), that, in order to help qualify PBXN-1 and PBXN-3 for military use, these explosives be checked in drop tests equivalent to the Dahlgren 305 cm. (10 ft.) drop on the studded steel plate. Since these explosives can be pressed and machined but cannot be cast, the Mk 54 depth bomb case could not be used, so a modification was made in the test, reference (1). A 152 Kg. (335 lb.) weight (equivalent to the average weight of the loaded Mk 54 depth bomb) with 3 studs protruding from its base was dropped on a fixed cylindrical charge about 12.7 cm. diameter and 30.5 cm. long, so that the studs penetrated the 1.6 mm. thick steel case wall and entered the explosive. The falling weight was guided by a stationary steel track. The explosive weight was in the order of 6 Kg. If a high order detonation occurs in this test set-up, repairs cost about $2000 and cause considerable delay in the program.

The Naval Ordnance Laboratory (NOL) drop test was developed in order to facilitate the acceptance of a new explosive for military use without the expense and delay now encountered in testing larger scale charges. New high temperature resistant explosives cannot be case loaded into the Mk 54 depth bomb cases. Some of these are very expensive to manufacture, especially in the development or pilot plant stage. The cost of a sufficient number of full scale charges would be prohibitive. The small size of the NOL test charges (approximately 227 gm.) not only reduces the expense to a reasonable figure, but allows the test to be carried on at NOL where explosive limits are small. The test equipment is so constructed that repair, after a high order detonation can be accomplished in about 15 minutes and the cost is negligible.

CONSTRUCTION OF EQUIPMENT

The arrangement of the NOL drop test equipment is shown in Figures 1 and 2. Since the NOTS test of 152 Kg. impacting on the area of 3 studs was considered more severe than the original Dahlgren test, it was felt that a weight of 45.4 Kg. (100 lb.) on one stud would be adequate for comparison. A higher maximum drop height makes the NOL apparatus more versatile. The shape of the drop weight was chosen as a cylindrical rod with an L/D ratio of more than 5/1. This configuration offers very little wind resistance and falls truer than a squat shape. It is simple to fabricate of standard materials, and easy to replace. The 19 mm. diameter stud was selected because this size was used in both the Dahlgren and NOTS tests. It protrudes 11.5 cm. from the base of the weight to be sure that all the energy of the drop is absorbed by its penetration into the charge. This concentration of energy causes the NOL test to be more severe (for a given height) than the NWL test where the impact force is distributed over a larger area of the case after a 25 mm. penetration of the stud. The stud is held in the drop weight by a set screw. This enables the operator to release the stud from the weight, after each drop, without disturbing its position in the explosive charge.

The stud and weight assembly is guided in its drop by cables passing through holes in the horizontal bars which are attached to the top and bottom of the cylindrical weight. The guide cables are kept taut by small hand winches, (Figure 4). They are secured to the base plate by cable clamps. When a detonation cuts the cables, a little more length is reeled off the winches, the ends are again clamped to the base plate, the slack is taken up, and testing is resumed.

The charge cases are made of steel tubing with an inside diameter of 38 mm. (1 1/2 in.), a length of 14 cm. (5 1/2 in.), and a wall thickness of 6.4 mm. (0.25 in.). One end is closed by welding on a disc of 1.6 mm. (0.062 in.) thick sheet steel. The thick wall tubing provides a confinement comparable to that of a large charge. The 38 mm. diameter was chosen as a standard tubing size which is easily procured, and is larger than the failure diameter of cast TNT. It is not anticipated that an explosive with a larger failure diameter will ever be tested. The cover disc, which is punched by the stud, is the same thickness as the Mk 54 Mod 1 bomb case. The straight cylindrical case allows loading of any kind, cast or pressed explosive.

The base which supports the test charge, (Figure 3) is constructed as follows:

(a) A steel plate 122 cm. (4 ft.) square and 4.5 cm. (1 3/4 in.) thick rests on a bed of blue crushed stone approximately 15 cm. (6 in.) deep.

(b) A steel plate 46 cm. x 69 cm. x 2.5 cm. (18 x 27 x 1 in.) rests on (a).

(c) A steel plate 30 x 36 x 2.5 cm. (12 x 14 x 1 in.), to which the guide cables are attached, is bolted on (b).

(d) A steel block 23 x 23 x 7.6 cm. (9 x 9 x 3 in.) rests on (c) and supports the 15 x 15 x 2.5 cm. (6 x 6 x 1 in.) steel witness plate.

The test base is completely encircled by a steel ring, reinforced by 2.5 cm. thick steel plate on the side toward the operators, and backed up on the outside by sand bags.

The weight is dropped by a solenoid operated release mechanism. The solenoid must be energized in order for release to occur. A power failure cannot cause an accidental drop. For further safety, two switches are installed in the power line. Both must be on in order for the solenoid to be energized. A mechanical stop has been installed (since Figure 3 was taken) in order to prevent the weight from impacting the charge, in case of an accidental drop during the raising of the weight due to mechanical failure. This stop is removed by pulling a lanyard after all personnel are behind the release shelter. The shelter is composed of a steel ring 182 cm. (6 ft.) high with a plank roof, (Figure 4 background).

ENERGY RELEASE

In order for proper comparison of test results, it is necessary for the energy released in the NOL test to compare favorably with that of the NOTS test. Neglecting air resistance and friction of the guide wires, the potential energy of the weight about to fall (equal to the kinetic energy at the point of impact) can be represented by:

$$E = \frac{WV^2}{2g}$$

where W = weight in kg.
V = velocity in m/sec.
g = acceleration of gravity in m/sec.^{2}

But

$$V^2 = 2\,g\,S$$

where S = the height of fall in meters

So

$$E = \frac{W\,2g\,S}{2\,g} = W\,S$$

In the NOTS test W = 152 Kg.
S = 3.05 m

and impact is on 3 studs of area 2.85 cm.^{2} or

$$E = \frac{152 \times 3.05}{3 \times 2.85} = \frac{462}{8.55} = 54.1\ \text{kg-m/cm}^2$$

In the NOL test $W = 45.4$ kg.

$S = 6.10$ m.

and impact is on 1 stud of area 2.85 cm.^{2}

$$E = \frac{45.4 \times 6.10}{2.85} = 97.2 \text{ kg-m/cm.}^2$$

Thus the available energy in the NOL test far exceeds that of the NOTS 305 cm. test. Also a drop height of 340 cm. at NOL is equivalent to the 305 cm. height of the NOTS test.

TEST OPERATION

The loaded test cylinder was placed on the witness plate, open end down, centrally located under the stud which protrudes from the base of the weight. When the stud was just touching the top of the test charge the weight was in the zero position, (Figure 3).

The weight was lifted by a hand winch (Figure 4) to some predetermined height. The cable which lifts the weight was marked at 30.5 cm. (1 ft.) intervals to facilitate height determinations.

When the test height was reached, the winch operator joined the release operator behind the release shield (Figure 4 background). The warning horn was sounded, the release was actuated, (Figure 5), and the following action was audible and also visible through a mirror set-up.

The operators returned to the test site. The stud was released from the weight by the set-screw, the weight was raised a few centimeters, the penetrated charge was removed, penetration was measured, and the witness plate readied for the next drop. The apparatus was checked out, before actually testing explosives, by drops on inert charges from 457 cm. (15 ft.) and 610 cm. (20 ft.). The release functioned properly, the stud struck the top of the charge centrally, its removal was accomplished readily, and penetration easily measured. Since that time many different explosives have been tested and the facility, although very inexpensive and simple in construction, has proved to be very satisfactory in its operation.

At first, the charges were cast into standard pipe with the sheet steel discs silver-soldered on. It was found that the pipe had a weak seam which was easily ruptured, and the soldering was broken by the hydraulic pressure caused by the penetrating stud. So seamless steel tubing was employed and the discs were welded. This produced the desired confinement. The studs first employed were made from standard bolts with the heads cut off. Consequently they had standard coarse threads, and square ends with a slight chamfer. In order to be consistent, the testing was continued with threaded studs which were made from threaded rod, cut to length with square ends and the corners burred.

TEST RESULTS AND CONCLUSIONS

Results of the tests made on fourteen explosives are listed in Table I. "No action" was recorded if the case was not ruptured even though in some instances there was a pop and a little smoke. "Low order" indicated a loud report and a rupture of the case, but no dent in the witness plate. A "high order" was listed if a crater was obtained in the witness plate, (Figure 6). The height reported in Table I is the lowest level at which no action occurred, or the lowest level at which the indicated action did occur.

It should be noted that, in general, the drop test data orders the explosives the same as the Bruceton type impact machine. In the case of Comp C-4 there is an apparent discrepancy. It was observed that, due to the soft, pliable nature of this explosive, much of it was forced out the open end of the case as the stud penetrated the other end. Possibly there would be more action if Comp C-4 was totally confined with a bottom as well as a top on the case. RDX/Wax 95/5 also appears to be more sensitive in the drop test than in the impact machine. There is no apparent real reason for this reversal.

I don't think there is enough real data yet. 9/13/63

DINA is by far the most sensitive explosive tested. There was at least low order action in all instances where the stud penetrated the case. There was no penetration at 31 cm. (1 ft.).

If this test were run in the same manner as the NOTS test we would say that "no action" at a drop height of 340 cm. (11.17 ft.) indicates that an explosive is acceptable for military use as a secondary since this drop height produces the same energy as the acceptable 305 cm. NOTS test. It is seen in Table I that all explosives down the list to, and including cyclotol, are in this category. The others, from cast pentolite on down are in the booster class. The opinion is stated in NOTS IDP 876 that the NOTS drop test at 5 ft. is comparable to the NWL test at 10 ft. on the basis of energy absorption per stud. If this is true the corresponding height in the NOL test is 5.6 ft. or 264 cm. The dividing line on Table I would then fall between cast pentolite and tetryl.

To date, however, the drops have been made in the following manner. If no action occurs, a higher drop is made. If low or high order occurs a lower drop is made, and so on. This accounts for the blanks in the table. In the cases of cyclotol, tetrytol, and tetryl the first drops resulted in low order action. Since we were trying to determine the maximum height for no action, the following drops were made from lower heights, and no high orders were encountered. If all tests were made from the same height all we could say of the materials is that they are, or are not, acceptable. By using the NOL method the relative sensitivity of the explosives is determined. This does not mean that complete confidence can be put on figures from this test, because various explosives react differently to different stimuli. It does mean, however, that results obtained in the drop test give a good indication of a given explosive's resistance to rough handling; and should be considered with results of other tests such as impact, card-gap, and cook-off, to get the overall sensitivity picture.

The NOL drop test has proven to be a very workable manner of ordering the relative sensitivity of various explosives to rough handling. Because of the small size of the test charges, a larger number of drops can be made, making results more reliable, and keeping the cost low. The shape of the container is such that any type of explosive is easily loaded.

RECOMMENDATIONS

It is recommended that the drop test facility be refined and made more permanent in order that the maximum information can be gleaned from each test. This would include a permanent steel tower (it can be very simple in construction), with a capability of a higher drop. Electric power should be supplied for operating the hoisting winch. A Fastax camera should be installed to record the impact action.

In the Card Gap Test the 50% point for DINA is 330 cards, reference (2), which is calibrated to yield 5.2 kilobars pressure at the lucite high explosive interface, reference (3). The pressure transmitted to the explosive is actually about 15% higher. A free falling weight of 9 kg. or more from a height of 1220 cm. (40 ft.) has an impact velocity of 15.5 m/sec. producing a pressure of 1 kilobar, reference (4). Since the

NOL drop test weight falls from a maximum height of only 610 cm. the pressure produced is much less than 1 kilobar. Thus it may be concluded that any initiation occurring in this test is not due to impact shock because this would require at least 5.2 kilobars for the most sensitive explosive tested. Initiation is probably the result of a "hot spot" caused by the penetrating stud. The remains of some of the cases, after low order action had occurred, showed a greater bulge at the middle or lower end of the tube, indicating initiation at or near the end of the penetration. The camera would enable one to determine at what depth of penetration initiation occurs.

It has been suggested that the threaded studs might have introduced some variables which are difficult to define or control. Possibly the threads, during the penetration of the charge case, may scrape off small hot particles of steel which would influence action of the explosive. The surface of standard threads varies with the method of manufacture, so the effects on the explosive may differ. A straight cylindrical stud with a square end would eliminate these possible difficulties, and the test would be more comparable with the NOTS and NWL tests which employ plain surfaced studs.

Opinions have been voiced that atmospheric conditions may have an effect on the sensitivity values obtained by this test. At present, records of the temperature and relative humidity are being kept for each test. If these records indicate discrepancies due to the weather, it is recommended that a program be initiated to determine exactly how much the test figures are influenced by atmospheric conditions.

It would be desirable, from the viewpoint of comparing this drop test with other laboratory sensitivity tests, to actually determine the 50% probability point of detonation in the true Bruceton statistical manner. A higher tower would be necessary to determine this point on the first seven explosives listed on Table I. Experience to date with present equipment indicates that a 32 meter tower height would probably produce action on TNT and similar explosives.

TABLE I

NOL DROP TEST DATA

Explosive	No. Drops	Height - cm No Action	Low Order	High Order	Bruceton Impact Hgt.* (cm)	Remarks
TNT(cast)	15	610	- -	- -	177	Pop & smoke on some drops. No cases ruptured
TNT(pressed)	10	610	- -	- -	150-215	" " "
HBX-1	10	610	- -	- -	90-150	" " "
H-6	10	610	- -	- -	100	Pop & smoke on some drops. No cases ruptured.
HBX-3	10	610	- -	- -	87	" " "
Comp C-4	10	610	- -	- -	47	
Comp B	8	519	610	- -	45-82	
Tetrytol	10	519	549	**	41	
Cyclotol (75/25)	10	305	366	**	35-42	
Pentolite (cast)	9	305	335	366	35	
Tetryl	10	244	285	**	26-50	
RDX/Wax (95/5)	10	244	285	396	47-63	
CH-6	10	153	183	183	28-34	
Pentolite (pressed)	10	153	183	183	20-26	
DINA	8	31	- -	46	22-24	No penetration of stud at 31 cm.

*NAVORD Report 3592, Factors Affecting the Behavior of Explosives to Mechanical Shock, G. Svadeba, 18 Dec. 1953, describes machine and outlines method of test. **Not determined

NOL DROP TEST

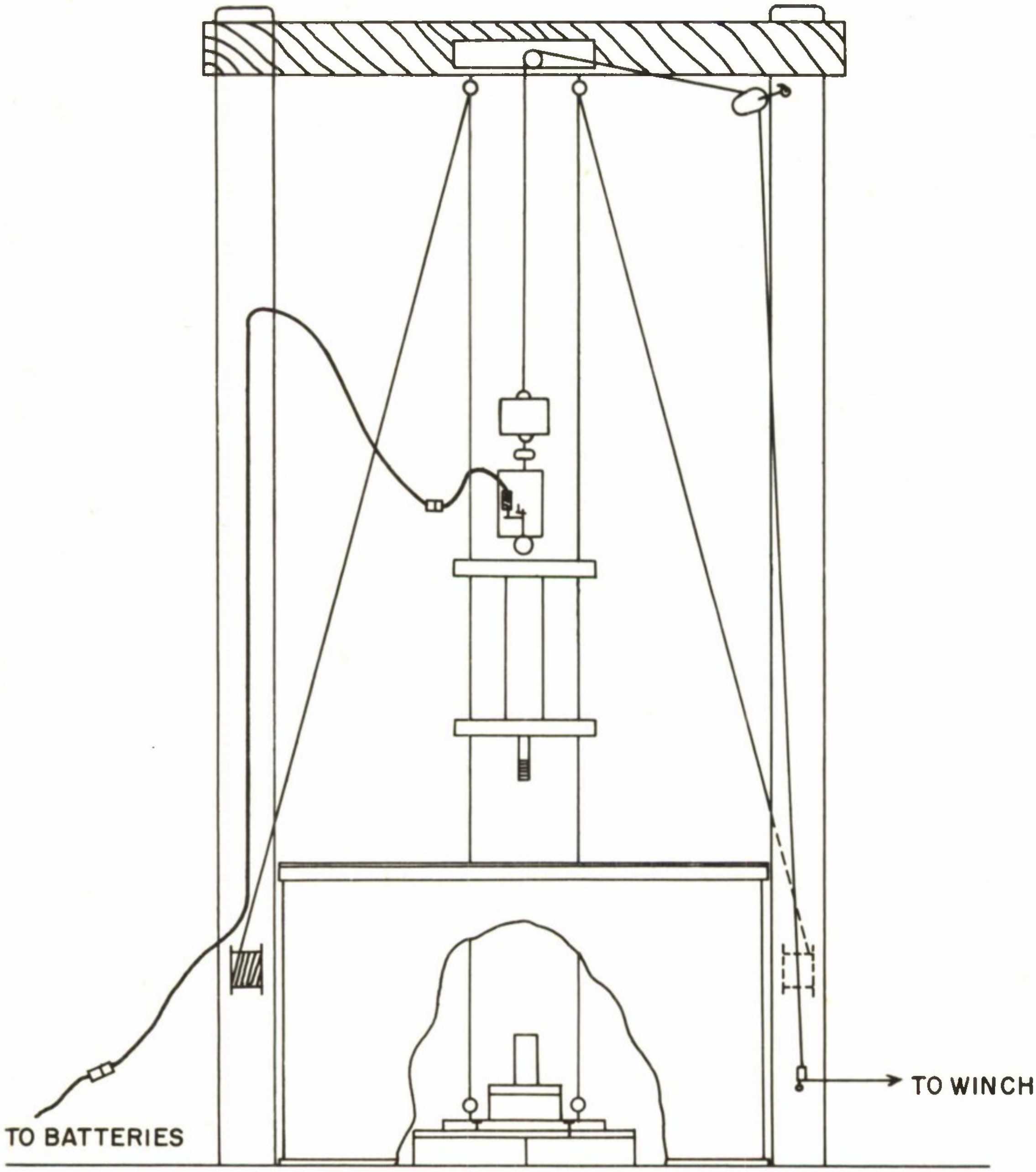

FIG. I TEST APPARATUS

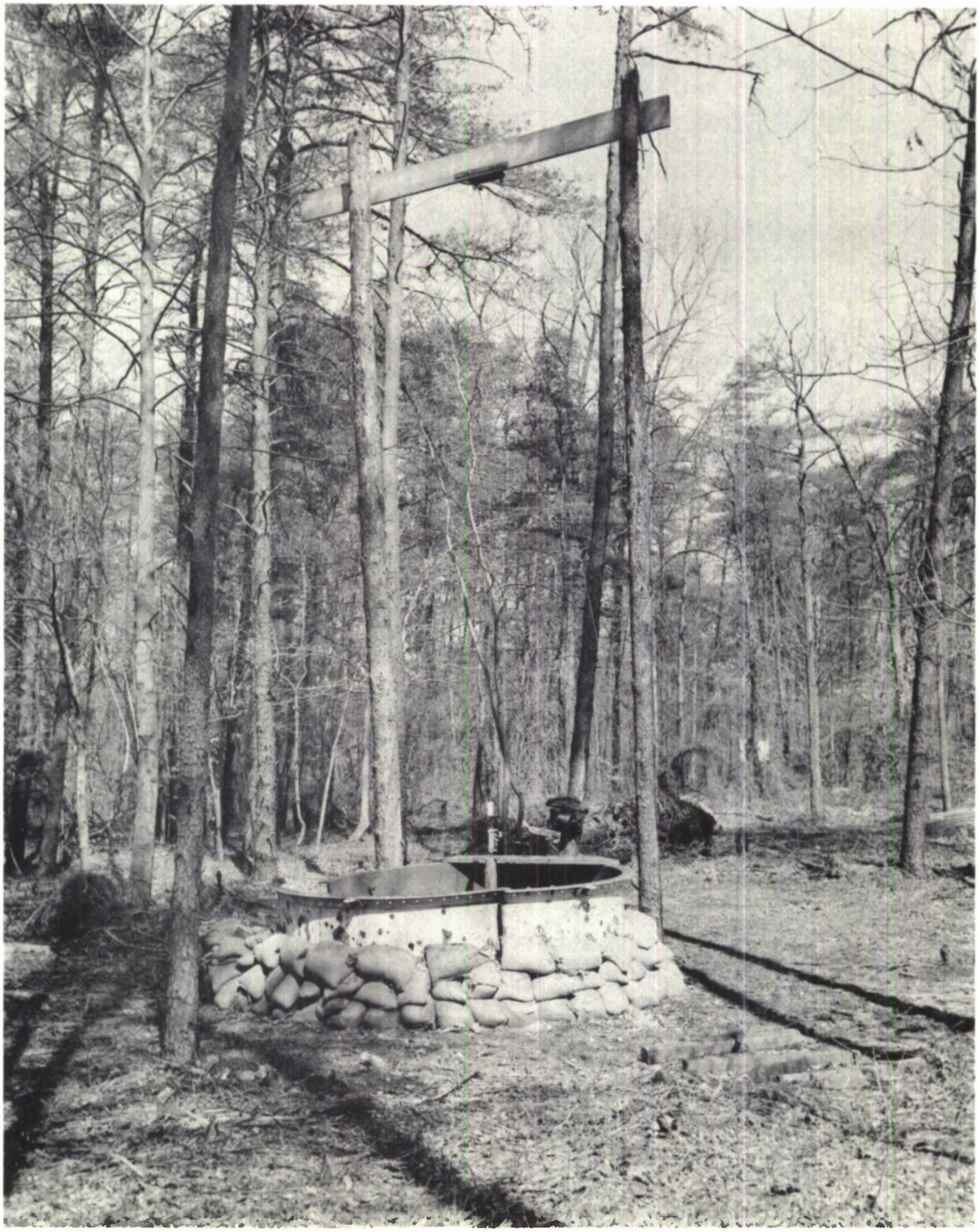

FIG. 2 DROP TOWER

FIG. 3 BASE, CHARGE, DROP WEIGHT AND RELEASE

FIG. 4 GUIDE WIRE AND HOISTING WINCHES

FIG. 5 SIGNALLING AND RELEASING SWITCHES

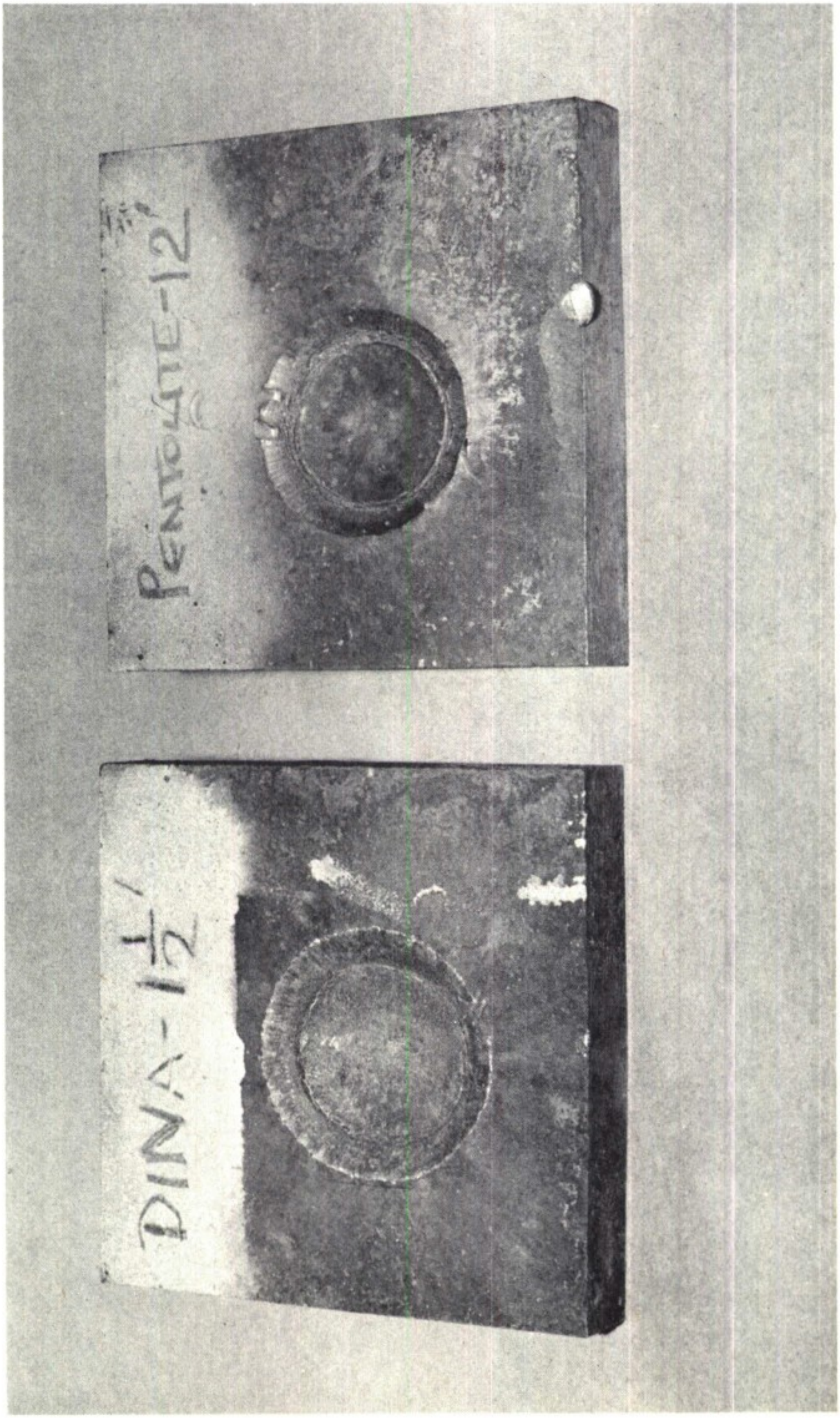

FIG. 6 WITNESS PLATES AFTER TEST

REFERENCES

(1) NOTS IDP 876, PBXN-1 and PBXN-3 Drop Tests, C. W. Falterman, 9 March 1960

(2) NOLTR 61-4, Large Scale Shock Sensitivity Test Compilation of NOL Data for Propellants, I. Jaffe & Others, 15 May 1961, Unclassified

(3) NAVORD Report 6876, The Attenuation of Shock in Lucite, I. Jaffe, R.L. Beauregard & A.B. Amster, 27 May 1960, Unclassified

(4) NOLTR 62-41, Safety Information from Propellant Sensitivity Studies, Dr. D. Price and Others, Confidential

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SOURCE	NOL technical report	NOLTR	SECURITY CLASSIFICATION AND CODE COUNT	Confidential - 7	CØØ7
REPORT NUMBER	62-150	62Ø150	CIRCULATION LIMITATION		
REPORT DATE	21 June 1961	Ø661	CIRCULATION LIMITATION OR BIBLIOGRAPHIC		
			BIBLIOGRAPHIC (SUPPL., VOL., ETC.)		

SUBJECT ANALYSIS OF REPORT

DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
Drop tests	DROT				
Naval Ordnance Laboratory	NOLA				
Naval Weapons Laboratory	NPGA				
Naval Ordnance Test Station	NOTS				
Drop testers	DROS				
Energy	ENER				
Release	RELE				

PRNC-NOL-5070/28 (5-62)